Process Balancing to Increase Coal Barging Efficiency: Case Study in Mining Company

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Abstract: This study discuss how line balancing was used at an coal mining business to improve the efficiency of coal barging. The research used a case study methodology, collecting and analyzing quantitative data to examine the consequences of balancing workloads among different operational phases in the coal barging process. A smoother workflow and less idle time resulted from the identification and removal of major bottlenecks in the loading and dumping phases. In order to improve the efficacy of line balancing in dynamic operational condition, future research should look into the effects of reducing working hours, including digital technologies like internet of things (IoT).

Keywords: improvement, kaizen, mining, transportation, waste

1. INTRODUCTION

The mining sector is essential to the global economy because it provides many different industrial sectors with vital raw materials. However, there are a number of obstacles which frequently arise which impact how efficiently mining operations move coal (Tampubolon & Dwito, 2024). The unbalanced workload at every stage of the coal transportation process is one of the major issues, as it causes queues and delivery process inefficiencies. Delays, increased operational costs, and an overall decrease in productivity resulted in the company. The application of line balancing techniques offers an alternative solution for this problem and improves the efficiency of coal barging. In manufacturing and assembly processes, line balancing is a commonly used technique that balances the workload evenly among different production or operating phases (Saptari et al., 2015; Kartika et al., 2023). By ensuring that every stage runs at maximum efficiency, this approach reduces idle time and eliminates all bottlenecks. Line balancing can be a tactical method to improve the flow of coal from the mine to the barge, minimize waiting times, and optimize resource allocation in the context of coal barging process. The business may improve delivery capacity and decrease delays by maintaining task balance at each stage of operations, thereby improving the overall efficiency of coal delivery.

The article discusses a case study of a mining company's use of line balancing to increase the efficiency of coal barging. In order to overcome these obstacles, the research focuses on identifying major bottlenecks in the coal barging operation and implementing line balancing methods. This study is to demonstrate the advantages of line balancing in improving operational efficiency, reducing costs, and improving efficiency in the coal barging process through an in-depth analysis of the company's daily operations. The case study's findings provide valuable knowledge for mining industry practitioners and researchers both. Through the practical demonstration of line balancing in actual situations, the study enriches our understanding of operational efficiency in mining operations. The results of the study can also be used as a guide by other companies concerning related issues, since they provide a framework for improving the coal barging process by carefully implementing line balance

2. LITERATURE REVIEW

As part of a production strategy called line balancing, machine and operator time are balanced to match the customer demand called takt time with the production rate. Takt time is the rate of production required to meet customer demand for parts or products. A production line is said to be completely balanced if its production time and takt time are exactly equal. If not, bottlenecks and surplus capacity should be eliminated by reallocating or rearranging resources. Stated differently, it is necessary to rebalance the number of humans and machines assigned to each task in the line in order to attain the ideal production rate (Lehtovaara et al., 2021). Takt time is equal to available production time divided by customer demand as described in Figure 1. Takt time is a tool for setting the production pace and rhythm and aligning it with customer demand (Soliman, 2020; Lehtovaara et al., 2021).

One of the most crucial components of the mining industry is the coal transportation process, which has an impact on the supply chain's overall effectiveness. Inefficient transportation can result in delays, interruptions, and increased costs for operation (Yaping & Bossman, 2021). Line balancing, which has been widely utilized in many industrial sectors to optimize workflow and eliminate wasted time, is one technique that can be used to increase transportation efficiency (Kurbandi & Widodasih, 2023; Manaye, 2019; Sitanggang & Hariadi , 2021; Ríos et al., 2012).

Figure 1. Takt Time (Source: www.oee.com/takt-time)

Application of Line Balancing in Industry

In order to reduce waiting times and improve production flow, line balancing is the process of balancing the workload equally among all stations or stages in an operating system. Line balancing has been used extensively in the manufacturing sector to increase productivity and process efficiency. Line balancing effectively reduced production cycle time and boosted efficiency in assembly systems (Dolgui & Proth, 2013; Saptari et al., 2015). Line balancing techniques can be used to a variety of operations, including those within the logistics and transportation industries, although their frequently employed in manufacturing. Line balancing works effectively on transportation systems as well, as these systems frequently experience congestion and inefficiency due to unbalanced workloads.

Application of Line Balancing in the Transportation of Coal

In the mining sector, moving coal from the extraction site to storage facilities or ports is a multi-stage, intricate process. If the job is not divided up efficiently, each of these phases—from loading the coal to loading it on the barge could result in a bottleneck or congestion. Line balancing is becoming a more important tool to handle coal transportation as supply chain efficiency is demanded more and more. Mining businesses might increase distribution of load and lower operating costs by balancing the coal loading. Despite the obvious advantages of line balancing, there are still a number of obstacles that must be solved before this technique can be used in the mining industry. One of the biggest obstacles is the distance fluctuations, environmental condition which frequently cause difficulties with line balance. The inadequacy of certain mines' infrastructure and equipment also presents challenges to the efficient application of this method. These challenges can be solved, however, with the development of automation technologies and data analysis. mining businesses can monitor and control transportation flows more effectively by utilizing real-time data analysis and Internet of Things (IoT) technologies, which would ultimately increase operational efficiency.

3. METHOD

This study uses a case study methodology to investigate how line balancing can be applied to increase a mining company's coal barging efficiency. This approach was used in order to acquire a comprehensive understanding of the actual situation in the industry and the practical steps the company has taken to eliminate inefficiencies. These are the steps that make up the method. A case study was carried out at an Indonesian coal mining firm which operates in Kalimantan. Logistics division, operational managers, field supervisors, and transportation operators are among the research subjects in this site, which focuses on the transfer of coal from the mine to the shipping port. This company was selected in part because of problems with workload imbalance and inefficiencies in the coal barging process that were found. Direct observation was used to collect data. To make it more practical, the barging process divided into four processes: loading coal into the truck (loading), hauling coal from stockpile to hopper (hauling), dumping coal to hopper (dumping) and transfer coal to barge by conveyor system (conveyor) as described in Figure 2. At different operating stations, observations were conducted on the coal barging activities, ranging from the coal loading procedure at the stockpile to the truck transportation and final transfer to barge loading conveyor (BLC) at the port as described in Figure 1. Every stage's cycle time will be recorded in order to identify any workload imbalances or bottlenecks. The method will be explained as below steps:

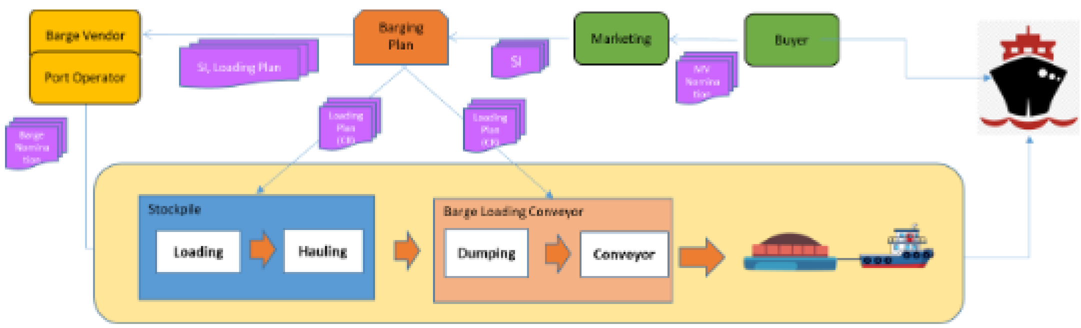

Figure 2. Coal Barging Material & Information Flow Chart

Identify Work Load: This step utilizing time study. The aim of time study is to calculate and identify the workload of every stage of coal barging, starting with the first data collection from loading process, hauling, dumping and loading conveyor.

Determine Bottleneck: This step determines the process which has highest cycle time and which process could not meet the takt time. The process stages that are causing the congestion will be identified based on preliminary observations and data analysis. There may be a bottleneck when the coal is being loaded, being transported by truck, or getting transferred in to the barges.

Workload Distribution: To ensure that each stage has a balanced cycle time, the workload will be redistributed after the bottleneck has been identified using kaizen techniques. This stage might involve re-arrangement of equipment, work sequence, reducing the number of trucks or allocating additional resources.

Kaizen: To improve the bottleneck, in this case the cycle time which are above takt time become the priority. Kaizen techniques has been used to reduce cycle time. Kaizen focuses on optimizing processes, increasing efficiency, and minimizing waste. At this research kaizen step used plan, do, check, action steps. For example, the highest cycle time was in loading process. Plan: the team find out the root cause and the team found that this was happened because the working space is too narrow for equipment to maneuvers, which lead to high cycle time. At that time, there were two fleets of loading equipment working in one stockpile slot. Do: the improvement team doing equipment arrangement by split the fleet working into two slots instead of single slot to enable equipment have enough space for maneuverings freely. The next kaizen will be described in Section 4, result and discussion. Check: the team check the result after re-arrange the equipment. Act: the improvement continuous to the next process bottleneck.

Evaluation and Analysis After Implementation: Following the application of line balancing, operational efficiency will be evaluated once again in order to compare the results with before implementation data. Cycle time, throughput (the volume of coal transported) are among the metrics that are analyzed.

4. RESULT AND DISCUSSION

To make sure that BLC system could meet the demand, takt time must be calculate and compare with cycle time of each station. Takt time is an important yet frequently tool for aligning production with demand and establishing flow in process. It is impacting capacity planning, process design, production scheduling, and plant floor operations. Takt Time is equal to available production time divided by customer demand. Table 1 show the calculation of takt time which is 166 second. This result come from customer demand for barge 270 feet size with 5200 MT normal capacity. Truck volume 24 MT, and the capacity will be fulfilled by 217 truck cycle (217 ritages). The company allocate time for 270 feet barges was 10 hours, means available time for one barge 270 ft was 10 hours. Using equation in figure 1 resulted in takt time 166 second.

Table 1
Takt Time Calculator

Demand	Quantity	Metric
Barge Quantity 270 Ft	5200	Metric Ton
Volume DT (MT)	24	Metric Ton
Truck Ritage	217	Ritage (rit)
Available time		
Hour/Day	12	Hour/Day
Effective Hour per shift	10	Hour
Available time per day	36,000	Second
Takt Time	166	Second/ritage

With takt time 166 second means that this is the pace of customer demand, thus all the process stage should meet the customer demand. After collecting the actual data from the field and it is shown in Figure 3. Thera are two processes exceed the takt time: loading process (231 second) and dumping process (170 second). Therefore, the improvement should be focus on loading process, because it will be a system bottleneck. Takt Time will help to see the flow throughout process and reduce waste by balancing the line (so each step moves at the same pace). A bottleneck is a point of congestion in a production system that severely slows the system. The inefficiencies brought about by the bottleneck often create delays and higher production costs.

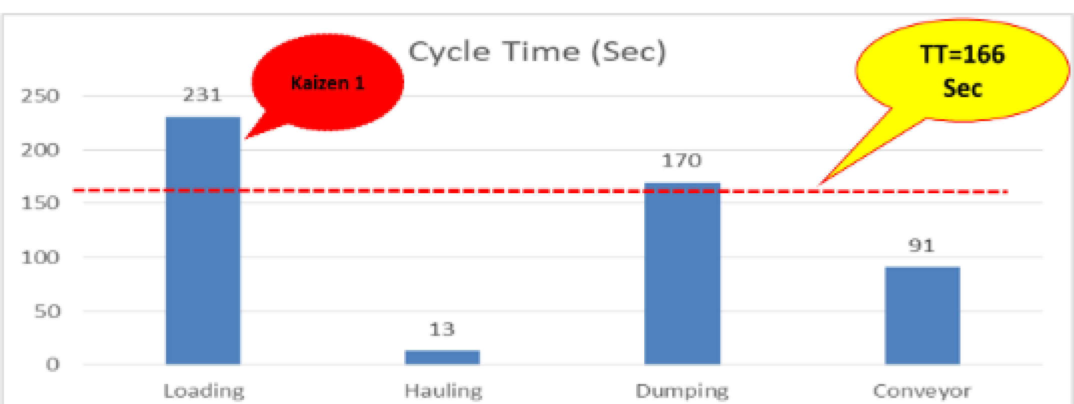

Figure 3. Cycle Time Analysis (Before)

The analysis has been made, the team find out the root of the problem and found that the slot of stockpile was too narrow. There were two-wheel loader and four trucks have been assigning to serve the barging process with hauling distance approximately 200 meters. The coal source assigned from one slot, but it was too narrow, there are no enough space for truck to make maneuver. So, some of the truck will stand far away when another truck doing loading process, and this situation increase cycle time of loading process. The solution for this problem was two split the equipment into two slots. One stockpile slot consists of one wheel loader and two trucks, so there will be enough space for trucks maneuvering. The kaizen result has reduced loading cycle time from 231 seconds to 116 seconds as described in Figure 4.

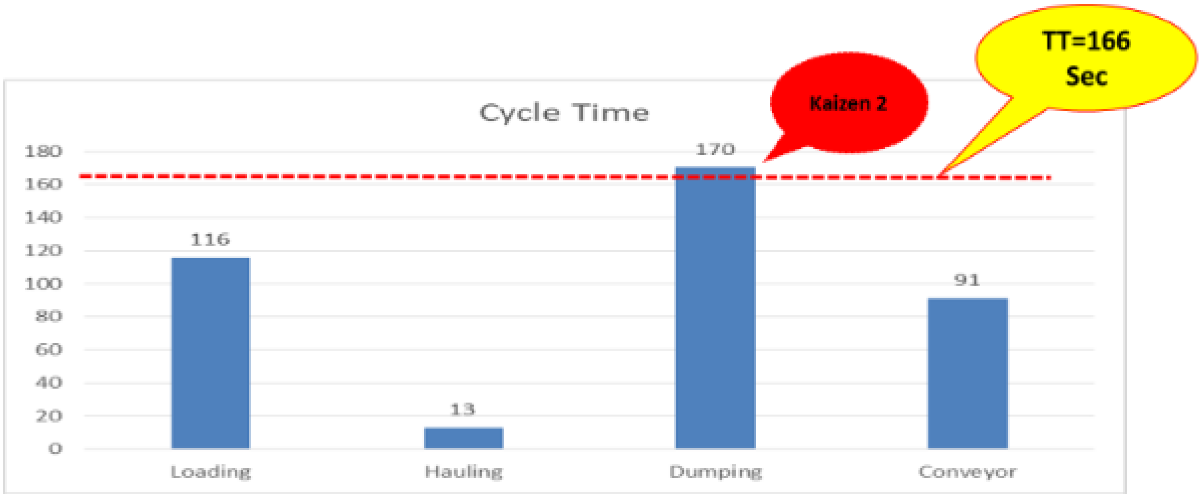

Figure 4. Cycle Time Analysis (After Kaizen 1)

Analysis has been carried out after Kaizen 1, the dumping process cycle time still above takt time, there for the team find out the root cause. The problem was the size of coal has clogged the hopper. Since the wide of the hopper gate was 50 centimeter maximum, therefore coal with bigger size will stop the coal flow to conveyor. To rectify this problem, the team doing resizing process especially for big coal. This happened because the type of the coal was manual crushed coal. After second kaizen has been made, the data was collected and the result the dumping process cycle time has reduce from 170 second to 140 second as described in Figure 5.

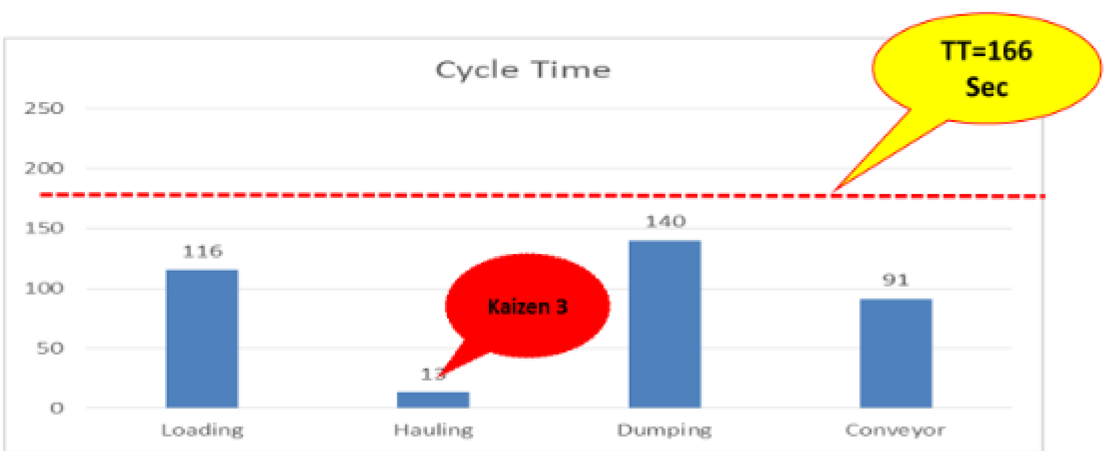

Figure 5. Cycle Time Analysis (After Kaizen 2)

After second kaizen has been executed, the dumping cycle time now below the takt time. The process able to meet customer demand. However, the system still unbalances, because the hauling system cycle time was to fast, compare to its next process. The actual situation in the field showed that some truck queuing in front of dumping area. Because hopper capacity unable to absorb the capacity of hauling which is bigger than hopper capacity. This situation will create waste on process, waste of waiting and waste of fuel. Therefore, third kaizen should be made. There are two option to overcome this problem. The team propose those two. The first was to reduce number of trucks, so the total cycle time of the hauling will increase. The second option was to arrange di hauling distance. Since there are two fleet of loading equipment, therefore distance combination will be made. One fleet hauling from slot with 200-meter distance and one fleet from another slot with 300–400-meter distance. This combination expected will increase the hauling system cycle time. The team expected the cycle time of hauling match with the cycle time of loading equipment as described in Figure 5. For this purpose, trial in the field should be made.

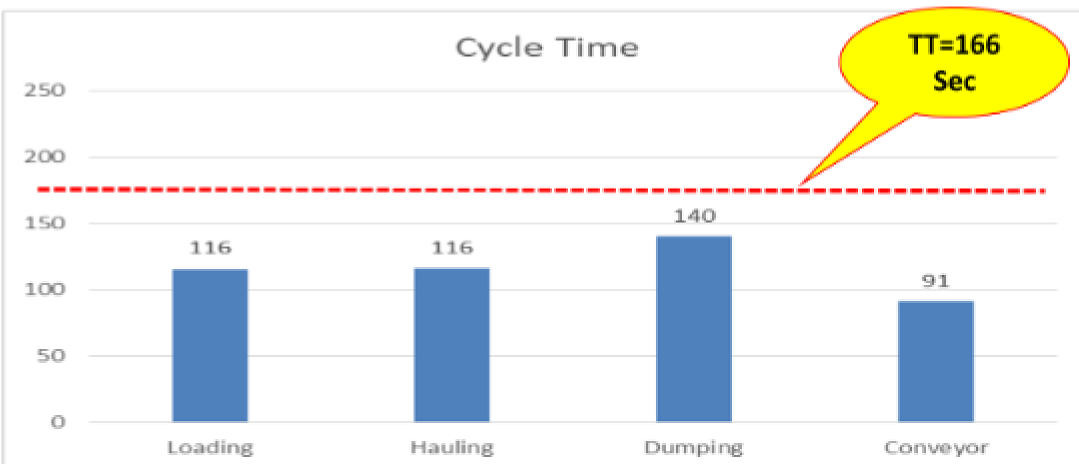

Figure 5. Expected Cycle Time of Hauling (After Kaizen 3)

5. CONCLUSION

The application of line balancing has been successful in increasing the mining company's coal transportation efficiency, as indicated by the data and analysis above. The company significantly decreased cycle time of loading process, decrease dumping cycle time and reduce waste of truck waiting, thus decreased operating expenses with a more balanced job distribution. Notwithstanding a number of obstacles, mostly associated with output volatility and infrastructural constraints, this study's findings show that line balancing is a dependable technique for raising system efficiency for coal transportation. Even though line balancing has been successfully applied, this study also notes a number of implementation-related difficulties. The environment condition creates significant problem, causing variations in the effort at every level. Even if the workload has been reduced, imbalances might still happen on days due to environment impact like rainy condition that force loading must stop due to slippery and safety concern.

Even though this study has shown that line balancing may effectively increase the efficiency of coal transportation, there are still a number of significant topics that need be thoroughly investigated in future study projects. Here are a few recommendations for further research: Reduce working hour from 10 hour to 8 hour for example, this will reduce the takt time. This will lead to potential solution to address this efficiency and productivity improvement. The time to complete one barge 270 feet will reduce. The second is real-time load balancing this will create rapid and real time data for improvement and fast decision making. To create more complex workload optimization models, future research could also make use of algorithm-based optimization techniques. Using this technique, simulation scenarios that can foresee different production situations and react to changes more rapidly can be created.

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